PROGRESS IN THE TREATMENT OF PLANT DISEASES IN THE UNITED STATES.

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INTRODUCTION.

In looking back over the work of the past century in the treatment of plant diseases, two facts immediately enlist attention: (1) That the last fifteen years have witnessed by far the greatest advances made, and (2) that in every step taken there has been shown the characteristic American spirit of striving to get direct practical results as quickly as possible. For the first three-quarters of the century there was practically no systematic attempt to obtain light on the diseases of crops. Of course, diseases have been recognized as long as plants have been grown, but in all these earlier years it was the custom to regard them more in the nature of obstacles, against which it was practically useless to contend, than as subjects for study and thought.

PRESENT CLASSIFICATION OF PLANT DISEASES.

A few words at this point in regard to present methods of classifying plant diseases will perhaps make clearer the discussion to follow. Briefly stated, diseases may be produced in three ways: (1) By living organisms acting as parasites; (2) by unfavorable environment in which the plant grows; and, (3) by combinations involving both organisms and environment. No line can be drawn between these groups, for their relations and interrelations are so intimate that sharp separation at any point is out of the question. The living organisms, such as fungi, bacteria, etc., produce diseases by attacking the higher plants and destroying them in order to build up their own structures. On the other hand, when the surroundings, such as unfavorable soil, too much or too little food, improper cultivation, excess of water, insufficient aeration of the soil, or other similar conditions occur, disease may follow without the action of such organisms as fungi or bacteria.

It might, however, be held that the plant ought not to be subject to disease produced by organisms, for if it were surrounded by conditions exactly suited to its growth and were at all times able to adapt itself to these conditions, growth would in a measure be perfect, consequently no disease could be produced by outside agencies. But the plant is always in a state of unstable equilibrium, and it is this fact

that makes it subject to the attacks of organisms and likely to be injured when any marked change of environment occurs. While this appears to be an element of weakness, it nevertheless affords vast opportunities, and is really the keynote to successful plant culture, as the writer will endeavor to show farther on.

EARLY THEORIES ON PLANT DISEASES.

It is not surprising that the man who grows plants looks to the weather as the source of all that is good or bad. In his own way he learns by experience that the weather has an important relation to the success or failure of his work, and he soon begins to connect certain weather conditions with what he sees going on about him. In all the early literature, therefore, references are found to the effects of "unfavorable weather," "meteorological disturbances," etc.

Other facts gained by long experience were also brought to bear on peculiar phenomena connected with plant diseases and their treatment. Thus, it was known at the beginning of the century and earlier that the injury from wheat rust was influenced by the presence of the common barberry plant. So strong was this conviction that laws were passed prohibiting the growing of barberry for ornament or for hedges. The opinion prevailed that the barberry caused rust, but it was not until many years later that its connection with rust was shown scientifically by the investigations of De Bary in Germany. It was also believed by many of the older agriculturists that smut was the direct result of a rupture of the cells of the plant itself, and that the rust of wheat was often produced by similar causes. Not only was this the general belief among many agriculturists, but it was credited by a number of workers abroad who made special studies of the subject.

About the year 1845, largely through the efforts of one or two investigators abroad, light began to dawn upon the nature of a number of the common diseases of plants, and these efforts were destined to have a marked influence on all future knowledge bearing on this subject. Although there was as yet no systematic attempt in this country to make special investigations, the work done abroad was gradually made known here, and through the agricultural press and other sources, became more or less familiar to farmers and others interested.

The great prevalence of the potato-rot fungus about this time (1845) gave a decided impetus to work on plant diseases. The rot swept over the earth, and many attempts were made to discover its cause and to provide a remedy. The relation of the parasite to the disease was worked out in Germany, and this knowledge soon became known to the farmers of this country. The same was true of wheat rust, corn smut, etc., so that even in these early days there was some knowledge of treating diseases by the direct use of remedies or preventives. This is particularly true of the smuts, which were among the first diseases to be controlled by the use of substances designed

to destroy the reproductive bodies of the fungi themselves. Aside from this, the principal efforts in the way of treatment were in the direction of giving the plants the best surroundings possible and treating wounds by the use of simple paints, wax, etc.

Experience had taught that blight of the pear and apple must be cut out, although believed to be due entirely to "atmospheric influences." This emphasizes the important fact that has already been referred to, that is, that although the growers of plants did not, as a rule, concern themselves much with the causes of diseases, their experience had taught them certain methods of treatment which in some cases are even to-day accepted as the best that can be followed.

THE BEGINNING OF MODERN RESEARCH.

From 1845 until 1861 there was considerable advance in knowledge concerning plant diseases, particularly as regards their causes, or in other words, the relation to them of certain parasitic organisms. This knowledge came about largely through the investigations of a few men in Europe. From 1861 to 1873 the accounts of investigators abroad were published from time to time in our horticultural and agricultural reports and in agricultural and other journals. There was an increasing interest in the subject, however, and it is not surprising that in 1873 and 1874 there was a marked tendency to advance in knowledge along these lines.

Prof. T. J. Burrill, of the University of Illinois, was one of the pioneers in this field. Early in 1874 he commenced publishing articles on the parasitism of fungi and the relation of various organisms of this kind to such diseases as leaf blights, rusts, and other maladies. The following year Dr. W. G. Farlow, of Harvard University, began a series of papers which were epoch making in their nature. These papers dealt with a number of important diseases of plants and treated them in a masterly way. Although up to this time knowledge as to combating such diseases was limited, the information obtained in regard to the life histories of the organisms and the manner in which they attack the host plants and cause their death was of great value in suggesting lines of action looking toward prevention. Farlow's papers were followed by similar ones by Halsted, Bessey, Trelease, Earle, Arthur, and others.

Early in the eighties the interest in the subject became marked, as may be seen by the increased number of papers and the fact that some of the universities and colleges were devoting time to lectures and studies relating to the work. The State agricultural experiment station at Geneva, N. Y., inaugurated some important work under the direction of Dr. J. C. Arthur, who was made botanist of the station in 1884, and whose work was almost entirely on the diseases of plants. This was really the first systematic attempt on the part of any station or organized body in the United States to undertake a

thorough study of the subject. Dr. Arthur published four reports, which dealt with a great number of important diseases. He paid particular attention to pear blight, which was recognized as one of the most destructive diseases of fruit in the United States, and had already been shown by Dr. Burrill to be due to bacteria. Dr. Arthur's work tended to establish more thoroughly the parasitic nature of a number of fungi. The keynote to the practical work of treatment had not yet been struck, but was to come later as a natural result of the studies made at this time.

THE EPOCH-MAKING PERIOD FROM 1885 TO 1895.

A careful study of events, such as are to be described here, shows that in nearly every case where a line of work stands out preeminently as having a marked influence on the welfare of a country, two things have conduced to this end: (1) Through writings, lectures, and other channels the public has been educated so as to understand its need in this direction, and (2) after the recognition of this need there has been the proper direction of the forces necessary to satisfy it.

Prior to 1885 much had been done toward educating the farmers and fruit growers to the necessity of protecting their crops. There was a well-grounded belief that many of the common and destructive diseases owed their existence to causes which could be discovered, and which if once known might be controlled. The time, therefore, was ripe for starting the work on a more extensive scale than had ever been done before. The demand at this time was largely for information as to the best methods of treatment from a practical standpoint. It was not so much a question of knowing what the diseases were as it was how to best get rid of them. Recognizing these questions and their importance, the Department of Agriculture inaugurated some work which was destined to have far-reaching effects. F. Lamson-Scribner, who was assistant botanist at the time, was active in bringing about a proper recognition of the importance of the work. He undertook the publication of papers, which appeared first in the report of the Botanist of the Department of Agriculture. Soon such an interest was awakened that the Commissioner of Agriculture, Hon. Norman J. Colman, took steps to have the work put on a sound basis. Small appropriations were obtained, and the Section of Mycology was established as a distinct branch in the Department. Fortunately, a great impetus was given to the work at this time by the efforts being made in France to find remedies for the downy mildew of the grape. When black rot, another American disease, appeared in the French vineyards, there was widespread alarm, and consequently renewed efforts to find means of checking it.

It is well to call attention to the marked difference in the conditions existing in France and in this country with respect to such matters. Our country is so great, and the possibilities of diversified culture so

numerous, that many farmers and fruit growers do not feel the necessity of putting forth any marked effort in treating the diseases. In France, however, the life of the community itself depends in many cases on the success or failure of a particular crop in that community, and so it was that the greatest pressure was brought to bear on the French Government to make a determined effort to check the ravages of downy mildew.

Through a fortunate accident—the sprinkling of vines bordering a roadside with bluestone and lime in order to prevent the pilfering of the fruit—there was discovered about 1885 a fungicide which was to have a marked influence not only on the welfare of France, but also on the interests of America as well. This fungicide thus accidentally discovered is the so-called Bordeaux mixture, which is made by combining copper sulphate, or bluestone, with lime. It has long been known that copper in various forms is able to destroy fungus spores, but it was not until the discovery of the Bordeaux mixture that a great impetus was given to the study of its effects on many plants. No one could have imagined the consequences which were to come from the combined use of two such simple things. Not only was the fruit saved from the thieves, but it was protected against mildew as well.

Soon after the success in France in the treatment of grape mildew with Bordeaux mixture, its usefulness was noted in this country by the Department of Agriculture and also by others. It was difficult, however, to convince fruit growers of the importance of making thorough trials of this and other preparations. This was one of the greatest obstacles that the Department met with in the early stages of the work. However, circulars were sent out describing the preparation of the fungicide and suggesting diseases that might be effectively treated with it. The success of the work was marked. Immediately there sprang up probably one of the most remarkable series of investigations and experiments ever witnessed in this or in any other country. Fungicides of many kinds were proposed and tested on a large scale, and extensive lines of investigation were inaugurated not only by the Department of Agriculture, but also by private individuals in various parts of the country.

In 1887 Professor Lamson-Scribner severed his connection with the Department of Agriculture, accepting an appointment to the chair of botany in the University of Tennessee, and the Department's work in this line was put in charge of the writer. The investigations were pushed forward as vigorously as possible; new lines of investigation were inaugurated, and a special effort was made to bring about practical results. Black rot of the grape was successfully treated in 1887, and the same year decisive results were obtained in controlling several potato diseases.

A great impetus was also given to the work in 1887 by the establishment of the agricultural experiment stations. By means of these

stations it was made possible for many of the States to inaugurate work not only in the study of plant diseases and their treatment, but also in many other lines of investigation as well. Several of the stations immediately commenced investigations, and as a result for the next eight years the educational work done throughout the country had the most remarkable effect in putting farmers, fruit growers, and others in possession of knowledge most valuable to them. During the period under consideration a revolution was wrought in our horticultural methods, and, as a result, it is now as rare to find people who are not thoroughly convinced of the importance of spraying as it is to find those who are satisfied that the cultivation of the soil is not necessary.

This vast amount of work on the fungicides carried with it the necessity of providing suitable apparatus for the application of the various preparations, there being a great need for such apparatus when the work was started. Just prior to the beginning of the important line of work in 1885 attention had been called to the value of the cyclone nozzle, an apparatus invented by Dr. W. S. Barnard while connected with the United States Entomological Commission. Although this nozzle was designed for the application of insecticides, it was found that with some minor changes it would be equally as valuable for use in connection with fungicides. There was also an urgent need in 1887 for suitable power pumps for the application of the various preparations. Some advances had been made with such apparatus in France, particularly in the knapsack forms, but such of these as were in actual use were more or less cumbersome, and none could be obtained in this country. Early in 1887 the first American knapsack pump was put on the market, largely through the efforts of Col. A. W. Pearson, of Vineland, N. J., who was one of the pioneers in the work of treatment. The machine was somewhat complicated, however, and did not attract the attention that it really deserved. In 1888 the writer devised a new form of knapsack spray pump, which was soon put on the market, and this became the pattern from which many designs have been made. In a few years such was the demand for apparatus of this kind that numbers of machines were manufactured. The knapsack forms of sprayers have had a marked influence in the success of the work described. Through them it was made possible to apply the remedies in the most thorough manner, a feature which is of the greatest importance in such work. As a direct result of this work many other forms of sprayers were designed; in fact, in this feature of the investigation the United States can well claim to have constantly led the way.

SOME RESULTS OF THE WORK.

The ten years' work just described was unique in its way. There was a united effort to concentrate on as many practical problems

as possible, with a view of solving these first and attending to the more difficult ones later. Immediate results were demanded, and by obtaining them confidence was engendered; and thus the foundation for future efforts was laid. Within the limits of such a paper as this, it is not possible to review all the direct practical results of the work in question, but a few examples will suffice.

GRAPE GROWING.

One of the most striking examples of results obtained is furnished by the grape. Grape growing in this country has had a curious history. At the beginning of the century numerous attempts had been made to introduce and grow the foreign or European varieties. It was recognized that in this vast country abundant opportunities were offered for the production of grapes and the manufacture of wine. Our native varieties were not considered of value, and for this reason all the early efforts were put forth in importing and testing the foreign, or Vinifera, vines. All the attempts in this direction, however, proved disastrous, mainly on account of several diseases, which, from all that can be gathered, were the same as those known to-day as downy mildew and black rot.

After many discouraging attempts to successfully cultivate these European vines, the work was in a measure abandoned and attention was turned toward our native varieties, many forms of which were found growing in the woods. Some of these vines proved to be resistant to the diseases, no doubt because through a long struggle for existence there had been a survival of the fittest, and these were by nature endowed with the ability to resist the various maladies which had been so destructive to European vines. The diseases being American, the European vines had had no chance to develop anything like natural resistance before being attacked.

The discovery of the value of some of our native kinds gave the grape industry a new impetus, but as soon as vineyards began to increase and cultivation brought about changes in the vines themselves it was found that the latter were becoming more and more subject to the attacks of their old enemies. Consequently there are recorded many disastrous failures in grape culture between 1850 and 1860, when mildew and black rot were veritable scourges. In a number of places where grape culture had been very profitable the vineyards had to be abandoned. New localities, in which the grape had not been tried, were now planted to vineyards, and for a time these produced remunerative yields, but it was only a question of time when the diseases reached these places and it became necessary to abandon them and again seek more favored localities.

By 1885 grape growing had been tried in most of the important sections of the country, and as the diseases continued to spread it was realized that something would have to be done or else the industry

would have to be abandoned. At this time the work of the Department of Agriculture commenced, but so many efforts had already been put forth to control the diseases and there had been so many failures that it required a great deal of encouragement to induce growers to even make thorough trials of the treatments proposed. By carrying on experimental work in typical regions, however, and by demonstrating by actual trials that the treatments were effective, the value of the work was fairly established, and consequently fungicidal treatments were rapidly adopted. The money value of this work to the grape grower can not be estimated. It has given viticulture a new lease of life and has furnished profitable employment in many regions which otherwise would have been abandoned, so far as this crop is concerned.

NURSERY-STOCK DISEASES.

Prior to 1887 no attempt had been made to control the many serious diseases which affect nursery stock in this country. The nursery interests had assumed immense proportions and the value of the output was worth millions of dollars. Nursery stock, such as apples, pears, plums, cherries, etc., had long been subject to a number of serious diseases, which mainly affected the foliage. Often as a result of these injuries it was found impossible to properly bud the stock, and a large part of it was therefore rendered worthless.

In 1888 the Department of Agriculture inaugurated the first experiment with a view of finding some means of holding these diseases in check. After several years' work it was clearly shown that some of the most destructive maladies could be controlled. Spraying nursery stock, therefore, has come to be a general practice, and has been the means of saving thousands of dollars to the growers every year. The Department and the State stations have gone hand in hand in this work, and some of the most striking features of the practical side of the investigations have come about through the efforts of the latter. Potato scab, the smuts of cereals, and many other diseases are now controlled as a result of the good work done by these organizations.

DEVELOPMENT OF EDUCATIONAL FEATURES.

Perhaps there is no more striking instance of the growth of this subject than that witnessed in the development of the educational features connected with it. In 1885 there were only three institutions besides the Department of Agriculture making an organized effort in the way of teaching or in experimental work of this character. Ten years later there were fifty colleges and stations engaged in the work, and no less than one hundred special investigators were devoting their time to it.

THE PRESENT AND THE FUTURE OF PLANT PATHOLOGY.

Since 1896 there has been a marked tendency toward a higher appreciation of a true science of plant pathology. The outlying problems have in a measure been solved and opportunity has been given to survey and take a clearer view of the fundamental questions upon which the future success of the work must depend. We are far enough along to see that a new epoch has begun—one which we believe is to place this country in advance of all others in getting the most from the soil with the least expenditure of time and money. Our farmers and fruit growers are intelligent, quick to perceive, and quick to act. They are now in possession of knowledge which gives them a decided advantage over their competitors in other countries, and therefore it will not be difficult with such men and such conditions as we have to build up a science which will have a marked influence on the welfare of the country

What then are the lines along which this science is to be built? First, we must recognize more plainly the possibilities within the plant—its plasticity and its ability to change; second, we must learn to look more carefully outside of the plant, that is, at its environment and the effects this may produce; and, third, we must discover the principles whereby the grower of plants shall be able to bring about such perfect harmony between the plant and its environment that an approximately ideal organism will result. This means that our aim should always be toward making two blades of grass grow where only one grew before.

The foundation of this work is physiology, involving a study of the phenomena of life itself. Here we learn the possibilities of future development, and here hinge the vital questions relating to nutrition and heredity. The pathology of the future, therefore, will not stop at the mere correction of conditions involving the loss of a crop or part of a crop. It will put within the power of the intelligent grower knowledge that will enable him to forestall injuries by furnishing conditions best suited to the development of the plant. We must bring to our aid many lines of work. Plant breeding will enable us to attain ideal forms. Selection will make it possible to fix these forms within certain limits. Nutrition goes hand in hand with breeding and selection. Chemistry and physics play important parts, and in the study of pathological phenomena themselves other branches of science will be brought to bear. Thus, as we have pointed out elsewhere, the highest aim of the investigator in this field will be not to deal with effects only, but to study causes, for it is only by such means that the greatest good can be accomplished.